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Evaluating carnivore harvest as a tool for increasing elk calf survival and recruitment

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Project Background

Since the early 1940s, estimated statewide elk population in Montana has increased eight-fold, partially because of management efforts conducted in response to public demand for increased recreational opportunities (Montana Fish, Wildlife and Parks 2004). Elk are an iconic species throughout the western United States and beyond, and play a large role across ecological (Kauffman et al. 2010), social (Haggerty and Travis 2006) and economic (U. S. Department of the Interior 2011) landscapes. However, since the early 2000's, declines in elk numbers and recruitment in some parts of the western United States have resulted in growing concerns that the recovery of large carnivores such as wolves (*Canis lupus*), mountain lions (*Felis concolor*) and grizzly bears (*Ursus arctos*) has limited elk populations (Bunnell et al. 2002, Cook et al. 2013). Thus, the recovery of large carnivores has shifted the focus of wildlife managers to attempt to understand and manage the effects of top-down predation forces on elk populations. Carnivore recovery is important to elk populations because predation has been shown to be a proximate limiting and regulating factor for many elk populations (Messier 1994, Hebblewhite et al. 2002. Garrott et al. 2008, Andren and Liberg 2015). Together with carnivore recovery, changing elk harvest management prescriptions, shifts in land use, and changing habitat and climatic conditions all contribute to a complex suite of variables with the potential effect on elk population dynamics. Because of these complexities, understanding the effects of predation on elk population dynamics is difficult and determining appropriate management actions is challenging.

To detect and respond to fluctuations in wildlife populations, managers require information on the factors that influence population dynamics. Survival of prime-aged females and recruitment can both have strong impacts on a population's trajectory (Gaillard et al. 1998, 2000; Eacker et al. 2016). However, while adult female survival is often high and relatively stable (Nelson and Peek 1982, Garrott et al. 2003), juvenile survival tends to be highly variable and consequently, may be a more common driver of ungulate population dynamics (Raithel 2007, Harris et al. 2008). Recruitment, which incorporates fecundity and juvenile survival to age l, represents an important demographic parameter that wildlife managers often use to track trends in population growth rates (DeCesare et al. 2012). Although direct assessments of juvenile survival using marked animals offers the most accurate and informative measure of recruitment, such data are difficult and expensive to collect and may not be a feasible option. As a less expensive and less time intensive alternative, age ratios (i.e., number of juveniles per 100 adult females) offer an index of recruitment often used by managers to monitor populations (Harris et al. 2008). Such extensive spatio-temporal data sets offer the potential for monitoring changes in recruitment, and assessing long-term trends in populations (Harris et al. 2008, DeCesare et al. 2012).

In the west-central area of Montana, MFWP administrative Region 2 supports a healthy black bear population, and the number and geographic range of wolves, mountain lions, and grizzly bears have expanded during the past 10 years. Hunting districts in three watersheds with high carnivore densities have experienced declining trends in elk numbers and recruitment, and are currently below elk population objectives. Mountain lion predation, and to a lesser degree wolf predation, have been documented as important causes of elk calf mortality in this region (Eacker et al. 2016). In an effort to reduce predation on elk in areas with high carnivore densities and declining elk numbers, wildlife managers have developed and applied integrated carnivore-ungulate management strategies over the past 5 years. In conjunction with reduced or eliminated antlerless elk harvest throughout most of the region, carnivore harvest quotas have been increased in an attempt to reduce wolf and mountain lion populations.

When wolf management returned to the State of Montana and hunting resumed in 2011, MFWP liberalized wolf hunting regulations for each of the following 3 years. These changes included adding a trapping season, removing the state-wide quota, extending the season, and increasing bag limits for individual hunters. Additionally, in February 2012 a mountain lion harvest management prescription that increased harvest levels, particularly of female mountain lions, was applied in efforts to reduce predation effects on elk in the western portion of MFWP Region 2, while still conserving mountain lion populations and providing the desired mountain lion hunting opportunity. The prescribed mountain lion harvest management regulations were designed to reduce lion density by 30% over a period of 3 years across approximately 60% of the region, and manage lions for stability, generally at current levels, across the remaining 40% of the region.

Although these steps were implemented to reduce predation on ungulate prey species, there is uncertainty over the ability of liberalized carnivore harvest management prescriptions to achieve harvest levels that will affect carnivore densities at the landscape level. Further, reducing carnivore densities may or may not result in increasing elk calf survival and recruitment because the degree to which predation by each carnivore species is compensatory with other biotic and abiotic mortality factors is unknown. As a result, the effectiveness of carnivore harvest as a tool for increasing elk recruitment and population size is unknown and has not been evaluated.

These recent changes in wolf and lion management in west central Montana provide a unique opportunity to build on a recently completed project and conduct a robust, multi-scale Before-After-Control-Impact evaluation of the effects of carnivore management on carnivore population density and elk calf survival and recruitment. During 2012 and 2103, we estimated pre-treatment mountain lion density in an area managed for mountain lion reduction (south Bitterroot area) and an area managed for stability (upper Clark Fork area). To assess the effects of mountain lion harvest management on mountain lion population density, we will compare mountain lion densities in these treatment and control areas before and after 4-years of increasing mountain lion harvest quotas in the south Bitterroot area.

To evaluate the effects of carnivore management on elk calf survival and recruitment more broadly, we will conduct a regional evaluation of elk recruitment ratios and a focused evaluation of elk calf survival in the south Bitterroot study area to detect changes in the rate of wolf and lion caused calf mortality. At the regional scale, we will use age ratio data collected during annual spring surveys to evaluate changes in elk recruitment during different carnivore population and management regimes. This will allow us to broadly evaluate factors affecting recruitment over an extended period of time. On a finer scale, we will compare baseline data on elk calf survival and cause-specific mortality collected prior to changes in carnivore management with data collected following 4 years of carnivore management to determine if lion predation and wolf' predation rates decreased, and if calf survival and recruitment increased. The baseline elk calf survival and cause-specific mortality rate data were collected as part of a project conducted in the south Bitterroot area during 2011-2013. Building from these efforts, the purpose of this project is to evaluate elk calf survival and cause-specific mortality, as well as carnivore densities, to evaluate effectiveness of the carnivore harvest management prescriptions that were designed to reduce carnivore densities and increase elk calf survival.

Location

Elk calf survival and mountain lion population estimation is focused primarily within Ravalli County, Montana. Portions of this project also occur in Mineral, Missoula, Granite, Deer Lodge, and Powell Counties.

Study Objectives (2016-2017)

For the 2016-2017 season of this study, the primary objectives were:

1. Initiate the first year of elk calf survival monitoring in the south Bitterroot Valley.
2. Initiate the winter 2016-2017 mountain lion population estimation fieldwork in the south Bitterroot Valley.
3. Evaluate the effects of wolf harvest management regulations on wolf harvest and population density.

Objective #1: Elk calf survival monitoring

To evaluate the effects of carnivore management on elk calf recruitment we are estimating survival and cause-specific mortality of elk calves in the south Bitterroot area. The southern Bitterroot valley study area, located in west-central Montana, has an area of 3,350 km^2 (Proffitt et al. 2015*a*). The southern Bitterroot includes the drainages of the East Fork and the West Fork of the Bitterroot watershed. The East Fork and the West Fork, hunting districts HD 270 and HD 250 respectively, are home to the two separate elk populations that we will focus on in this study. Additionally, the East Fork population has a migratory segment with a summer range in the Big Hole Valley (HD 334, Proffitt et al. 2015 *a*).

The East Fork study area encompasses 1,719 km^2, and has an elevational range of 1,100-2,800 m. Portions of the East Fork are heavily roaded, and the area is 18% private land. In comparison to the West Fork, the East Fork consists of more modest terrain, and is characterized by heavy agricultural use and open grasslands which give way to timbered slopes, sub-alpine, and alpine terrain (Proffitt et al. 2015 *a*).

The West Fork study area encompasses 1,437 km^2, and has an elevational range of 1,200-3000 m. The West Fork is comprised mostly of public land (95%), with high road accessibility at lower elevations giving way to few roads at higher elevations (Proffitt et al. 2015*a*). The West Fork is characterized by heavily forested areas and lower riparian grasslands which are replaced by alpine terrain at higher elevations.

We will estimate calf survival in the southern Bitterroot and compare it to the baseline data collected in the same area prior to changes in carnivore harvest regulations. By comparing the rates of cause-specific mortality of elk calves attributed to mountain lions and wolves to those taken prior to liberalized carnivore harvest regulations, we will evaluate the effectiveness of using carnivore harvest management to decrease direct predation of elk calves.

1.1 Elk calf capture, sampling, and monitoring

Elk calf capture and sampling

We captured neonatal elk calves from 27 May to 6 June 2016. We used a combination of ground and helicopter search effort to locate calves in both the East Fork and the West Fork. Due to rugged terrain, search efforts in the West Fork were more reliant on helicopter crews to spot adult female elk and their calves. We captured a total of 81 neonatal calves. Of the 81 calves, 43 were in the East Fork population, 13 were in the Big Hole Valley and part of the migratory East Fork population, and 25 were in the West Fork population.

Once captured, we hobbled and blindfolded calves. We outfitted each calf with a TW-5 VHF ear-tag radio transmitter purchased from Biotrack LtD., Wareham Dorset. Each transmitter was designed to detect movement and emit an increased pulse rate indicating a mortality event if no movement was detected within four hours. We recorded the sex, weight (kg), right hind-leg length (cm), chest girth (cm), and the lengths of the outside edge of both the left and right incisors (mm) of each calf. Field crews estimated calf age based on several characteristics such as dampness of coat, mobility, condition of hooves, and development of dew claws.

Figure 1.1 *Hobbled and blindfolded elk calf during spring captures. Note ear-tag radio transmitter in right ear.*

Additionally, to supplement sample size of marked calves in the survival study, we captured and radio-tagged 40 additional approximately 6-months-old calves from 21 December 2016 to 5 January 2017. We captured winter calves using a combination of chemical immobilization or net-gunning delivered from a helicopter. Search efforts were allotted based on the number of remaining tagged calves in each part of the study area. We fit calves with a radio transmitter as previously described, and we also recorded chest girth and sex for all calves.

Table 1.1 *Number of calves sampled in the East Fork and West Fork study areas during neonate (spring) and 6 month (winter) captures.*

	East Fork	West Fork
May-June 2016	56	20
Dec. 2016-Jan. 2017	25	20

Calf survival monitoring

Using a combination of ground and aerial telemetry, we began monitoring calf survival and movement on the day following their capture. From date of capture to 31 August, we monitored calves every day due to high rates of neonate mortality reported in previous studies of elk calf survival (Barber-Meyer et al. 2008). After 31 August, we monitored calves 4-5 times per week and will continue with this schedule until calves reach age 1.

In addition to survival monitoring, we used aerial telemetry from fixed-wing aircraft to obtain relocations of each calf once a week from date of capture to 31 August. We used fixed-wing aircraft mounted with radio telemetry equipment to collect relocation data for each calf. We acquired a directional signal for each calf using radio telemetry, and flew in a straight line until we were directly over the calf. Once we pinpointed the general location of each calf, we circled the area, and used telemetry to identify the exact location. Most often, we could see the group of elk that the calf was a part of. We took GPS waypoints of the exact location of each calf. Due to hunting seasons in the area, relocations were not taken from 31 August – 27 November. We will use relocations of calves in conjunction with risk factors that vary spatially such as weather, forage, and carnivore resource selection covariates to quantify the effects of each on calf predation risk.

1.2 Elk calf survival and cause-specific mortality

When a mortality event was detected, we promptly located the mortality site and performed a detailed necropsy to determine the cause of mortality. We categorized mortality sources as mountain lion predation, wolf predation, bear predation, coyote predation, unknown predation, unknown cause, unknown fate/tag loss or natural non-predation. We used characteristics such as consumption pattern, location and presence of claw marks, location and presence of subcutaneous hemorrhaging, width and presence of bite marks, and general features of the kill site to draw a conclusion about each cause specific mortality event.

Figure 1.2 *Cache pile consisting of grass and twigs covering an elk calf carcass.*

At the mortality site, we searched the area for signs of carnivores including hair, scat, signs of struggle, bed sites and cache piles. Any hair and scat from potential carnivores that were found in the area was collected, placed in desiccant, and submitted for DNA analysis to definitively determine carnivore species. To differentiate predation and scavenging, we removed the skin to look for possible hemorrhaging around bite marks to indicate predation. In addition to a field necropsy, we also swabbed areas likely to contain carnivore saliva, such as sites of subcutaneous hemorrhaging and chewed ear tags. We used Dacron swabs sterilized by 95% ethanol. Swabs were placed in desiccant and submitted for DNA analysis.

In the event of a natural non-predation-related mortality where an untouched calf carcass was found, the entire carcass was collected and submitted for a more thorough lab necropsy by a wildlife veterinarian. To date, we have collected and submitted three such calf carcasses for necropsy, and are awaiting results.

As of February 1, 2016, we have recovered 49 ear-tags. Of the 49 tags collected, 39 were confirmed elk calf mortalities. The remaining 10 recovered tags were classified as "unknown fate" due to a lack of evidence needed to determine that the calf was dead (Table 1.2). From date of capture to August 31st, 2016, only two of thirty calf mortalities were located >24 hours after the monitoring crew detected a mortality signal, which enabled us to perform necropsies at most mortalities. The three leading causes of known mortality were bear predation, natural non-predation, and lion predation (Table 1.3). We were unable to classify all dead calves to a predating carnivore species when insufficient evidence was present at the mortality site. Thus, we classified causes as unknown cause or unknown predation based on the evidence from necropsies (Table 1.3). To date, DNA results from samples taken during necropsies have enabled us to assign four mortality events to a specific source of mortality when the field necropsy only revealed predation but not the species of carnivore involved. In three such cases, saliva swabs taken at sites of subcutaneous hemorrhaging and bite marks contained carnivore DNA, (2 mountain lion, 1 wolf) indicating that the elk calf was still alive while being bitten by a particular carnivore. In the 4th case, carnivore hair samples collected during a necropsy were submitted for DNA analysis. The resulting positive carnivore identification, paired with the data collected during the necropsy, was enough to classify the mortality as wolf predation.

Table 1.2 *Fate of tagged calves by sampling period. Neonates were tagged during May and June 2016 and 6-month calves were tagged during December 2016 – January 2017.*

Calf Fate	*East Fork*	*West Fork*
Live	*36*	*36*
Dead	*31*	*8*
Unknown Fate	*9*	*1*
Total	***76***	***45***

Table 1.3 *Causes of mortality of all tagged elk calves by elk population.*

Cause of Mortality	East Fork	West Fork	Total
Bear	1	4	5
Lion	5	0	5
Wolf	1	1	2
Natural Non-Predation	7	2	9
Unknown Predation	5	1	6
Unknown Cause	13	0	13
Unknown Fate	8	1	9

Objective #2: Mountain lion population estimation

To assess the effects of mountain lion harvest management on mountain lion population density, we will compare mountain lion densities in a treatment and control area before and after 4-years of increasing mountain lion harvest quotas in the treatment area. During 2012 and 2103, we estimated pre-treatment mountain lion density in portions of the area managed for mountain lion reduction (south Bitterroot study area) and the area managed for stability (Upper Clark Fork study area, Figure 2.1) in MFWP Region 2. During the 2016-2017 period of this study, our objective was to collect data to estimate mountain lion abundance in the southern Bitterroot study area.

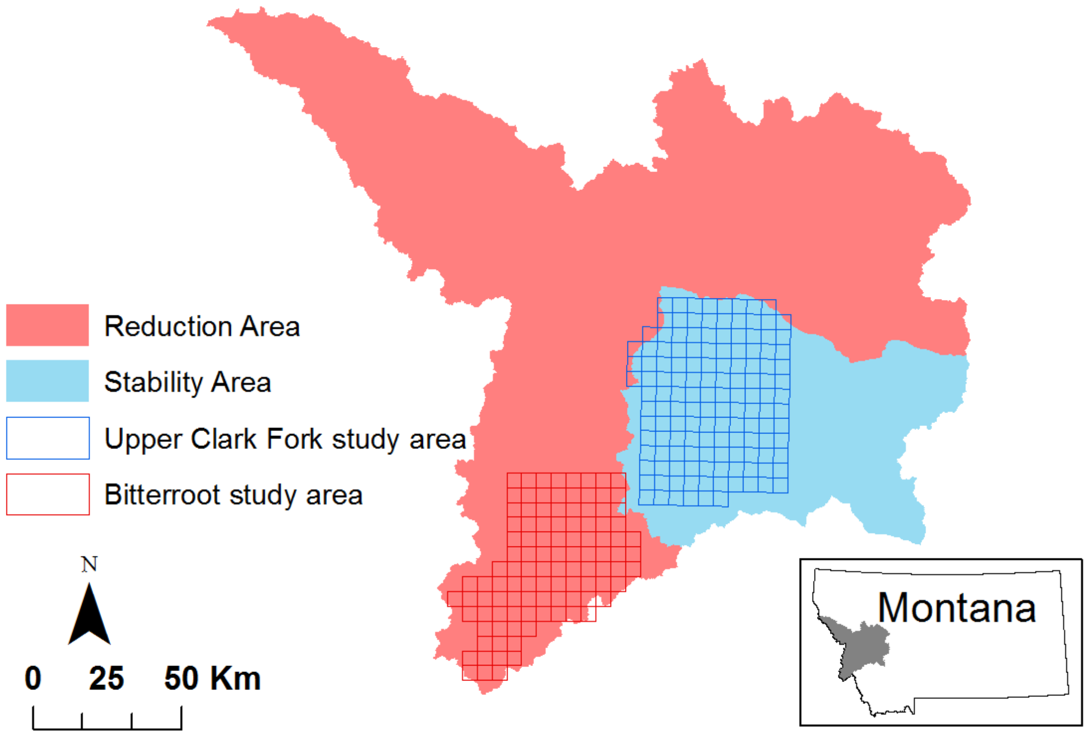

Figure 2.1 *Mountain lion harvest management goals in west-central Montana during 2012-2015 were to reduce mountain lion density by 30% across a portion of the region (shaded red) and maintain stable densities across a portion of the region (shaded blue). The south Bitterroot study area (red grid) was located in an area managed for a 30% reduction in mountain lion. density and the Upper Clark Fork study area (blue grid) was located in an area managed for maintaining stable mountain lion density.*

2.1Mountain lion harvest regulations and harvest

The southern Bitterroot (Ravalli County) study area includes hunting districts (HD) 250 and 270 and is within the watershed being managed for population reduction. In December 2012, median mountain lion density was estimated at 4.5 (95% CI = 2.9, 7.7) and 5.2 (95% CI = 3.4, 9.1 mountain lions/100km^2 in HD250 and 270 respectively (Proffitt et al. 2015*a*). The 2011 regulations included a subquota of 3 females in both hunting district (HD) 250 and 270, equating to 1.8 female licenses per 1,000km^2 (Table 2.1). In 2012 and 2013regulations included 14 special licenses with subquotas of 7 females in both HD 250 and 270, equating to 4.2 female licenses per 1,000km^2. After 2013, female harvest levels were reduced. In 2016, regulations included subquotas of 3 and 5 females in HD 250 and 270 respectively, equating to 2.4 female licenses per 1,000km^2.

The Upper Clark Fork (Granite County) study area includes portions of HDs 210, 211, 212, 213, 214, 2015, 2016 and 217 and is located with the watershed being managed for stability. In December 2013, median lion density was estimated at 1.6 mountain lions per 100 km^2 (MFWP, unpublished data). The 2010 and 2011 regulations for these areas included female subquotas equating to 1.2 female licenses per 1,000km^2 (Table 2.1). In 2012 and thereafter, regulations included female subquotas equating to 0.5-0.9 female licenses per 1,000km^2.

Table 2.1. *Mountain lion harvest quotass and harvest in the two hunting districts in the south Bitterroot study area. The south Bitterroot study area is located within a watershed managed for mountain lion population reduction, and included portions of HD 250 and 270.*

[1] During 2009-2011, there was no male subquota, only a female subquota and total harvest quota.
[2] There was a boundary change that expanded HD 270 and reduced the size of HD 250.

Year	*HD 270 Harvest Quota*			*HD 270 Harvest*		*HD 250 Harvest Quota*			*HD 250 Harvest*		*Female licenses per 1000 km²*
	Female	Male	Total	Female	Male	Female	Male	Total	Female	Male	
2001	0	3		0	4	0	5		1	4	0.00
2002	0	3		0	3	0	5		0	5	0.00
2003	0	2		0	2	0	5		0	5	0.00
2004	0	1		0	1	0	2		0	3	0.00
2005	0	2		0	2	0	3		0	6	0.00
2006	0	3		0	4	0	4		0	3	0.00
2007	0	3		0	2	0	4		0	4	0.00
2008	0	3		0	1	0	4		0	1	0.00
2009	1	-	10[1]	1	4	1	-	10	1	3	0.60
2010	2	-	15	1	8	2	-	15	2	3	1.20
2011	3	-	20	3	6	3	-	20	3	4	1.80
2012	7	7		6	7	7	7		9	5	4.20
2013	6	4		7	4	6	4		4	6	3.60
2014[2]	4	5		5	5	3	5		1	3	2.10
2015	5	6		2	6	3	5		2	5	2.40

Table 2.2. *Mountain lion harvest quotas and harvest in the Upper Clark Fork study area. The Upper Clark Fork study area is located within a watershed managed for maintaining stable mountain lion populations, and included portions of HD 210, 211/216, and 212/215/217.*

Year	*HD 210 Harvest Quota*			*HD 210 Harvest*		*HD 211/216 Harvest Quota*			*HD 211/216 Harvest*		*HD 212/215/217 Harvest Quota*			*HD 212/215/217 Harvest*	
	Female	Male	Total	Female	Male	Female	Male	Total	Female	Male	Female	Male	Total	Female	Male
2001				3	2	9	7		4	2	6	4		6	4
2002	1	4		1	1	2	4		2	1	6	4		6	4
2003	1	2		1	2	3	2		2	3	6	4		6	5
2004	1	5		1	2	3	2		3	2	6	4		1	3
2005	1	2		0	2	3	2		0	1	2	4		2	3
2006	0	2		0	2	0	2		0	0	0	4		0	3
2007	0	2		0	2	0	2		0	2	0	2		0	1
2008	0	2		0	1	0	2		0	2	0	2		0	0
2009	0	2		0	2	0	2		0	2	0	2		0	2
2010	2	-	4[1]	0	2	4	-	10	2	4	1	-	4	0	2
2011	2	-	4	2	2	4	-	10	1	4	1	-	4	0	3
2012	0	7		0	2	2	5		2	3	0	6		0	6
2013	0	3		0	5	3	5		2	2	0	6		0	7
2014	1	3		1	2	3	5		2	2	1	6		2	7
2015	1	3		1	3	3	5		1	4	1	6		1	6

Table 2.2 continued
[3]During 2010-2011, there was no male subquota, only a female subquota and total harvest quota.

Year	*HD 213/214 Harvest Quota*			*HD 213/214 Harvest*		*Female licenses per 1000 km^2*
	Female	Male	Total	Female	Male	
2001	1	1		0	0	2.33
2002	1	1		0	1	1.45
2003	1	1		1	0	1.60
2004	1	1		0	0	1.60
2005	0	1		0	0	0.87
2006	0	1		0	0	0.00
2007	0	1		0	0	0.00
2008	0	1		1	0	0.00
2009	0	1		0	1	0.00
2010	1	-	2	2	1	1.16
2011	1	-	2	1	2	1.16
2012	1	2		1	2	0.44
2013	1	2		2	2	0.58
2014	1	2		1	2	0.87
2015	0	2		0	3	0.73

2.2 Mountain lion population estimation in the south Bitterroot study area

To estimate the winter 2016-2017 mountain lion population density in the south Bitterroot study area, we applied similar field methodologies and sampling protocols within the same study area as the 2012 study to ensure that our 2016 mountain lion population estimate is comparable to the 2012 estimate. The winter 2016-2017 mountain lion population density estimate will provide an estimate of mountain lion density at the beginning of the 2016 hunting season. We are using a DNA-based spatial capture recapture approach (Proffitt et al. 2015*b*). We overlaid a 5 km x 5 km grid across the study area and assigned each cell a grid identification number. We randomly generated a list of grid cells and started search effort each day in the randomly assigned grid cell. Mountain lion hair, scat, and muscle samples were collected by hound handlers and trackers for genetic analysis to identify individual mountain lions. When a fresh mountain lion track was located, the hound handler would release trained hounds to locate and tree the mountain lion. Tracks were backtracked and inspected to determine if the mountain lion was independent or associated with a family group, and group size was recorded. Muscle samples were collected from treed animals using biopsy darts fired from a CO_2-powered rifle (Palmer Cap-Chur brand). When older mountain lion tracks were located, a tracker or houndsmen would backtrack the tracks and collect any hair or scat samples along the tracks. All field crews used a Global Positioning System to record the length (in km) and location of their search effort. Harvest and management removals occurred during the sampling period and we included samples collected from harvested animals within the study area in our analysis and population estimates. In Montana, the hide and skull of all mountain lions harvested must be presented to MFWP. During the mandatory check, inspectors collected a muscle sample from each harvested animal. We also collected samples from harvested lions in all adjacent hunting districts to determine if animals marked within the study area may have moved out of the study area.

Figure 2.2 *Mountain lion treed during sampling efforts.*

Tissue samples will be genotyped to identify individuals using 12 variable microsatellite loci (Biek et al. 2006). Sex will be assigned by genetic analysis. Mountain lion density estimates will be generated using a spatially-explicit Bayesian hierarchical model for estimating abundance that accounts for opportunistic sampling methods and differences in individual capture probabilities (Royle et al. 2009, Gardner et al. 2010, Russell et al. 2012, Proffitt et al. 2015*b*). To validate space-use parameters estimated by the spatial capture-recapture model, we are also radio-collaring a sample of up to 14 mountain lions to collect movement and location data. These data will be used to estimate actual activity center locations and home range sizes during the sampling period, and validate accuracy of parameter estimates from the spatial capture-recapture model.

Beginning December 3, 2016, hound handlers systematically searched designated areas and began collecting mountain lion hair, scat and muscle samples. As of February 1, 2017, a total of 91 person-days and 7,645 km of search effort has occurred (Figure 2.4). A total of 5 hair, 4 scat, 33 muscle samples have been collected. Additionally, 5 muscle samples have been collected from harvested mountain lions in the study area, and 57 samples have been collected from harvested mountain lions in adjacent areas. A total of 5 male and 4 female mountain lions have been fitted with GPS collars programmed to collect a location every 2 hours for 2 years. An additional male was captured but not collared, as the age was estimated at <18 months. Field sampling is currently still underway and will continue until March 31, 2017.

Figure 2.3 *Research team collaring sedated mountain lion.*

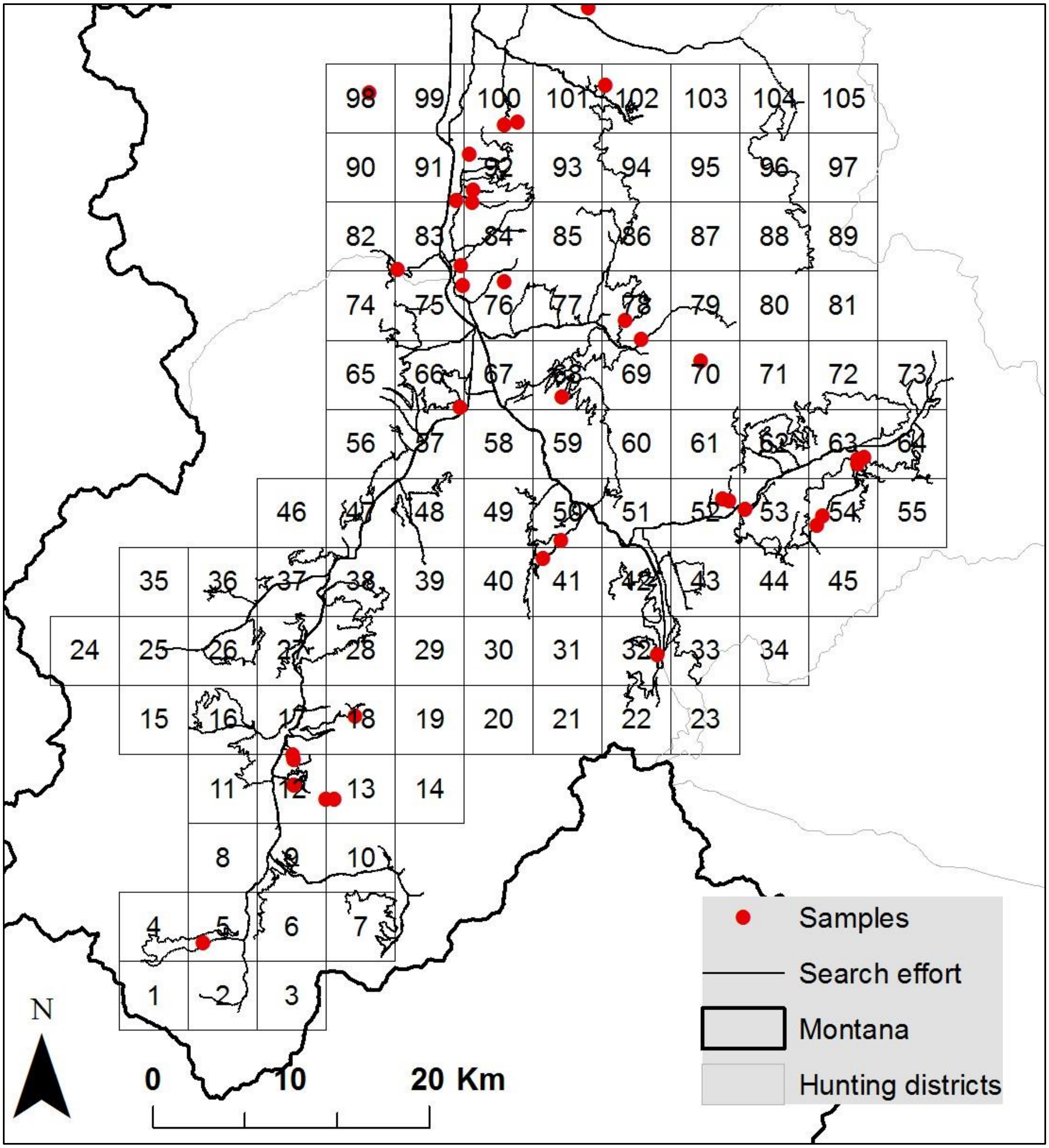

Figure 2.4 *The mountain lion search effort (black lines) and locations of samples (red circles) collected to date within the south Bitterroot mountain lion sampling area (black grid).*

Objective #3: Evaluate the effects of wolf harvest management regulations on wolf harvest and population density.

Prior to 2011, wolves in the Bitterroot Valley were part of the experimental non-essential population that resulted from the reintroduction of wolves into the Central Idaho Experimental Area in 1995-96. In May 2011, wolves in Montana became subject to state management authority guided by the Montana Wolf Conservation and Management Plan. Across Montana, minimum wolf counts increased steadily until 2011. Since 2011, the statewide minimum counts and population estimates have been stable to declining, and local population abundance varies annually with harvest management goals, management of livestock-wolf conflict, and other biological factors (Coltrane et al. 2016).

As part of the west-central Montana integrated carnivore-ungulate management plan to reduce carnivore densities, wolf harvest management prescriptions were implemented in the south Bitterroot study area to reduce wolf population densities. Our objectives are to evaluate the effects of wolf harvest management regulations on realized wolf harvest and population density in the south Bitterroot study area.

3.1 Wolf harvest regulations and harvest

Between 2008 and 2011, wolves in Montana were delisted, relisted, and then delisted again (Hanauska-Brown et al. 2011). This process resulted in a Montana wolf hunting season in 2009, no hunting season in 2010, and then wolf hunting seasons from 2011 through the present. Since MFWP most recently regained wolf management authority in 2011, wolf harvest limits and hunting season dates have been liberalized, and the use of specific trapping methods has been approved. Since 2011, there are no wolf harvest limits for HD 270 or 250 areas. Harvest regulations are based on combined hunting and trapping bag limits of wolves per person. In 2012, the wolf harvest regulations limited each person to harvesting no more than 3 wolves, with no more than 1 taken during the rifle season. In 2013 until present, the wolf harvest regulations limited each person to harvesting no more than 5 wolves, with no more than 1 taken during the rifle season.

All hunters and trappers are required to report all harvested wolves to MFWP. We used hunter and trapper reports to track the number of wolves harvested annually from mandatory reporting records (Table 2.3).

Table 2.3 *The annual harvest quota and reported harvest of wolves in the in the HD 270 and HD 250 area of the south Bitterroot study area during 2001–2016.*

Year	*HD 270 Harvest*	*HD 250 Harvest*
2008	*0*	*0*
2009	*2*	3
2010	*0*	0
2011	5	6
2012	5	8
2013	6	4
2014	3	1
2015	2	2
2015	2	2

3.2 Wolf population estimation

MFWP uses a combination of radio-collaring efforts, direct observational counts, remote cameras, and track surveys to annually track the wolf population, document pack size and breeding pair status of known packs, and determine pack territories. Ground and aerial tracking occurs 1-2 times per month to locate VHF and GPS collared animals and count the number of wolves travelling together. Additional information on sightings, breeding activity, mortalities, and human-wolf conflicts is collected throughout the year. This information is used to estimate the minimum count of wolves per hunting district on December 31st of each year (Coltrane et al. 2016).

In 2000, MFWP counted a minimum of 7 wolves in the entire Bitterroot Valley, and the minimum count increased to a high of 74 in 2011. In 2011, there was a minimum of 28 wolves in the West Fork (19.5 wolves/100km^2) and 18 wolves in the East Fork (10.5 wolves/100km^2) of the south Bitterroot study area (Table 2.4).

Table 2.4 *The estimated minimum count of wolves in the HD 270 and HD 250 area of the south Bitterroot study area during 2001-2016.*

Year	*HD 270 Minimum count*	*HD 270 Minimum number per 100 km²*	*HD 250 Minimum count*	*HD 250 Minimum number per 100 km²*
2001	2	0.12	5	0.35
2002	5	0.29	5	0.35
2003	Not available	Not available	4	0.28
2004	Not available	Not available	6	0.42
2005	Not available	Not available	11	0.77
2006	10	0.58	11	0.77
2007	17	0.99	14	0.97
2008	15	0.87	19	1.32
2009	13	0.76	24	1.67
2010	20	1.16	30	2.09
2011	18	1.05	28	1.95
2012	13	0.76	22	1.53
2013	12	0.70	16	1.11
2014	18	1.05	16	1.11
2015	13	0.76	10	0.70

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